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ABSTRACT

The study examines the rise and fall of the floppy disk as a common data storage device from 1971 to 2010. The analysis led to the identification of three stages in the rise and fall of the floppy disk, i.e. the “new dawn”, 1971–1990s, the decline stage in the 2000s and then the phase-out period. From the 1970s to the 1990s, the floppy disk gained dominance and became a leading storage device propelled by its superior features and capacity relative to the old-fashioned punch cards and magnetic tape. Yet, by the early 2000s, it was on a path to terminal decline precipitated by the emergence of competing storage devices and limitations of the floppy disk. The study highlights the effects of the technological revolution which ultimately led to the floppy disk being superseded by more reliable, high-capacity and robust storage devices such as CD-ROM, DVD/Blu-Ray discs, USB memory stick and cloud computing. The study charts the transitions from the floppy disk to CD-ROM and then to cloud computing and the underlying drivers. The study led to the identification of multiple competing technologies and competing forces punctuated by events which, over time, helped to precipitate the decline. The implication for theory and practice are identified and examined.

Keywords: Technological obsolescence; innovation; floppy disk; decline; history; strategy.

1 Introduction

Since the last quarter of the twentieth century, technology obsolescence and technological revolutions have become increasingly common as technological breakthroughs have ushered in the introduction of new products, thereby rendering many existing or old technology products obsolete (Bartels, Ermel, Sandborn & Pecht, 2012; Christensen, 1997; Afuah & Tucci, 2003; Sarpong, Dong & Appiah, 2016). In today's globalised world, many industries are increasingly shaped by these forces (Eggers, 2012, 2014; van de Kaa & de Vries, 2015; Amankwah-Amoah & Sarpong, 2016). In spite of frequent occurrences of technology obsolescence and technological revolutions, there has been little research into either what factors precipitate these shifts or how the underlying processes of obsolescence unfold in the face of changes in the wider environment (see Sandborn, 2007, 2015; Bartels et al., 2012). In the past few years, research has suggested that technologies often chart different life courses before becoming obsolete (see Bartels et al., 2012). Nevertheless, our understanding of the processes inherent in a technology becoming obsolete remains limited.

The purpose of this study is to examine why and how some technologies become obsolete. For the present study, our focus is confined to the case of the floppy disk, a technology which was one of the most widely used storage devices in the last quarter of the twentieth century before eventually becoming obsolete in the first decade of the twenty-first century. By the end of the first decade of the twenty-first century, the floppy disk was on a permanent path of decline and had largely disappeared as a common data storage device. Generally speaking, computers required a floppy disk drive (FDD) to be able to read the content of a floppy disk (BBC, 2015). As such, although our analysis focused mainly on the floppy disk, the analysis touches on developments in the FDD industry.

In developing our arguments, the study makes two main contributions to innovation, strategy and business history literature. First, although multiple arrays of technologies have been rendered obsolete,

innovation and strategy scholars who have traditionally examined such issues have sidestepped them. The paper builds on and extends prior scholarly works by developing a sequential framework to explicate the rise and fall of the floppy disk. In so doing, the paper adds to the growing body of research which demonstrates that technological revolution stems from the introduction of new technologies punctuated by multiple milestones, shifts and revolutionary breakthroughs (Bartels et al., 2012; Suarez, 2004; Kuhn, 1970). This is a departure from much of the existing literature on innovation and technological revolutions, which has focused on shape and competitive dynamics (Sood & Tellis, 2005; see also Amankwah-Amoah, 2016a, 2016b).

Second, although scholars have suggested the need to examine why and how technologies become obsolete, our understanding of the driving forces behind it remains limited (Bartels et al., 2012). The paper develops a framework of factors which, over time, precipitated the demise of the floppy disk. Furthermore, the historical approach adopted helped to respond to the growing calls to bring historical perspective into the study of industrial change and firm behaviour (see van de Kaa & de Vries, 2015).

The remainder of the article proceeds as follows. In the next section, a review of the literature on technology obsolescence and technology revolutions is presented. This is then followed by a review of the case-based approach to data collection and analysis. In the final section, the implications of the findings and directions for future research are examined.

2 Technology obsolescence and technological revolutions: An integrated review

Technology obsolescence in this context refers to a situation where an existing technology is seen to have reached the end-of-life stage (Bartels et al., 2012). This relates to technological revolution which is the process of one technology superseding another to gain dominance (new technologies displacing their predecessors) (Bartels et al., 2012; van de Kaa & de Vries, 2015). Ample theoretical and

empirical works have demonstrated that both technology obsolescence and technological revolutions can be precipitated by performance of a given technology relative to the available alternatives (Pecht & Das, 2000). A stream of research rooted in technology trajectories (Dosi, 1982) has long attributed the displacement of technologies by new technologies to superior features and performance offered by the new alternatives designed to accomplish the same objective (Adner, 2002; Schilling, 2013). Technological superiority refers to a technology's performance vis-à-vis competing alternatives which then determine its ability to gain dominance (Suarez, 2004). A line of research indicates that technological superiority, where a format outperforms alternatives, can contribute to the demise of the non-performing or underperforming format (van de Kaa & de Vries, 2015).

It has been suggested that technologies with sub-standard performance and functionality can be superseded by new ones (Christensen, 1997). Technological superiority can play a pivotal role in determining the fate of an existing technology when there are large variations in the performance or functionality differences between an old technology and its competing alternatives (Suarez, 2004). As such, technology obsolescence stems from the usefulness of a technology relative to the alternatives' reliability, dependability and durability (Bartels et al., 2012; Christensen, 1997). Another stream of research has indicated that technologies, which fail to meet users'/consumers' preferences in terms of functionality, speed, cost and capacity are more likely to be rejected by users over time, thereby becoming obsolete (Shy, 1996).

One line of research has indicated that the pace of technology decline and becoming obsolete is often predicated on the speed of adoption by users of new technology (Shy, 1996). As technology gains traction and the number of users increases, it can exert pressure on existing alternatives, thereby rendering some obsolete (Shy, 1996). A well-established body of research has attributed technological revolutions to factors such as incumbent technology's inherent limitation and superior features, and

performance of the new technology (Bartels et al., 2012; Christensen, 1992, 1997; Levinthal, 1998). These factors over time eventually cause the old technology to lose its appeal as more consumers switch to the alternative. Prior research has attributed the technology revolutions to firms' incentives to finance and develop superior technologies to enable them to carve out a segment of the market and ultimately develop a unique source of competitive advantage (Shy, 1996). Prior research has demonstrated that technology revolutions may stem from limited functionality, slow speed and limited accuracy of the existing technology which force users, individuals and companies to switch to the available alternatives (Afuah, 2009; Bartels et al., 2012).

The arguments thus far suggest that technology-specific functionality relative to the alternatives play a pivotal in sealing its fate. Offering a different theoretical argument, some scholars have suggested that technology becoming obsolete is often driven by market forces, which occurs when it becomes uneconomic for the product manufacturer to continue production (Bartels et al., 2012). Taken together, technology-specific factors, user preferences and requirements, and market forces interact to trigger the process of decline leading to obsolescence. Prior scholarly works have demonstrated that some technologies can pass through stages before becoming extinct (Pecht & Das, 2000). Technology obsolescence can be viewed as life cycle, which entails phases such as introduction, growth, maturity, decline and phase-out and obsolescence (Pecht & Das, 2000; Solomon et al., 2000). Technology obsolescence is treated here as a sequential stage model which delineates the interactions and effects of technology-specific and external factors. The technological revolutions can be viewed as a stage-model, punctuated by a series of events which reflect emergence of alternatives, dominance battle and eventual demise of uncompetitive technology, as illustrated in Figure 1. The contention here is that technology obsolescence can be viewed as a technological revolution process that unfolds over time, punctuated by environmental and technology-specific factors. One notable absence from the existing

literature is the lack of examination of the precipitating factors and how they manifest over time. The purpose of this article is to begin to fill this void in our understanding.

Insert Figure 1 about here

3 Data collection and analysis

The context for the study is the case of the floppy disk. A case-based research method was adopted to help provide a much deeper understanding of the rise and fall of the floppy disk (Yin, 2003, 2011). This approach is in line with prior scholarly works which considered the single-industry approach as being suitable for building theory (Sandström, 2015; Yin, 2003). As Christensen (1993) observed a few decades ago, studying the history of the floppy disk has the potential to enrich our understanding of technology revolutions and competing technologies. Given that much of the accumulated knowledge on such old technology and its historical trajectory are in an archival form, the study adopted the archival approach to data collection (see Amankwah-Amoah & Durugbo, 2016). The analysis focused on the period from 1971 (when the device was introduced) to 2010 when many analysts declared “the floppy is dead” (Ulanoff, 2010), “RIP Floppy Disk” (Thomas, 2010), “a fond farewell to the floppy disk” (Grossman, 2010) and “floppy disks are officially dead” (Fiegerman, 2010). The data collection began by assembling secondary reports, videos and news articles on floppy disks from various organisations such as IBM, BBC, *The New York Times*, *The Economist* and the *Financial Times*. The sources yielded data in forms such as video recordings, documentaries and reports. Furthermore, governments and industry reports on the technology were also examined. The company-specific information, such as reports and press releases from pioneering firms in the floppy disk industry such as FUJI and IBM, was identified and examined. The data sources included

government reports and academic publications on capacity of the floppy disk. The sources yielded an array of materials on the history of data storage devices.

The analysis started with a familiarisation of past news stories on the floppy disk. The data were organised into an “event history database” (Van de Ven & Poole, 1990). This entailed organising the materials around the key themes at the time which then formed the basis of our findings. In order to analyse the data, a narrative account (Maguire & Hardy, 2013; Eisenhardt & Bourgeois, 1988) was developed which entailed identifying the milestones, key events and emergence of technologies that have shaped the industry and influenced the rise and fall of the floppy disk. An event history from the industry databases was constructed, charting the developments in data storage devices. From this insight, a clearer narrative of how the floppy disk emerged and eventually became extinct in modern technology stores was developed, which formed our “discursive-event history database” (Maguire 2004). Based on this, the information was classified to help establish the chronology of events. Figure 2 depicts three distinct periods in the development and demise of the floppy disk against a backdrop of declining cost of data storage.

Insert Figure 2 about here

4 Research site: Floppy disk, the beginning of an era

In this section, a brief snapshot of the evolution of the floppy disk is presented to help provide the backdrop to the analysis. Since the invention of the computer, scientists, designers and engineers have sought effective and efficient ways to access, store and transfer data (Christensen, 1993). The development and emergence of the floppy disk was a giant step in this direction.

The floppy disk originally emerged in the 1970s and became one of the leading data storage devices before eventually declining and becoming obsolete. The development of the floppy disk technology can be traced as far back as the 1960s before taking off in the subsequent decade. Computers required an FDD to be able to read the content of a floppy disk and the FDD is regarded as one of the leading innovations in data storage history (McKendrick & Wade, 2009; Shugart, 1998). When the floppy was first introduced in 1971 by IBM who commercialised technology, it was heralded as a “revolutionary device” capable of transforming the ways and means of storing data (Watson, 2010; BBC, 2007). In 1971, the floppy began to attract more attention following IBM’s decision to test-market in Europe (McKendrick & Wade, 2009). From the outset, the floppy disk was the brainchild of a group of engineers in the US led by Alan Shugart and was designed to store programmes and data files, superseding the old-fashioned punch card and magnetic tape as a medium for data storage (McKendrick & Wade, 2009, p. 622; BBC, 2007). The punch cards actually preceded the computer and entailed punching holes into cards which could be read by any computer (Long, 2005).

One of the accomplishments of the floppy disk was that, prior to the late 1970s, many software applications such as word processing and accounting were written by the computer owners themselves. The advent of the floppy disk made it possible for companies to write programmes, store them on the disk and sell them in the marketplace (IBM, 2015). In a sense, the advent of the disk provided individuals with the opportunity to be able to load software programmes into their personal computers which helped to usher in the computer revolution (Watson, 2010; IBM, 2015). The floppy disk allowed computers to read and write data, and became a primary means of storing and transferring documents and files between computers (Watson, 2010). In 1972, Alan Shugart left to establish Shugart Associates which eventually introduced the lower-cost, 8-inch, form-factor FDD (Markoff, 2006; Pollack, 1990). By 1973, Shugart was offering a relatively low-cost model of the 5.25-inch disk by targeting a different class of smaller computers outside of the corporate data centre (Markoff, 2006;

Pollack, 1990). In the 15 years after 1971, the floppy emerged as one of the dominant media for data storage.

In 1983, IBM launched the 10-megabyte hard disk to users which was a turning point in offering more room to store data. As this stage, when PCs first entered the workplace, they had small hard disk drive capacity but a large hard disk drive with limited storage space (Long, 2005). For the 1970s and 1980s, the floppy disk was seen as revolutionary (Grossman, 2010). In the mid-1990s, more than five billion floppy disks were sold annually worldwide. The limited capacity of the disk meant that individuals and companies were required to own multiple copies just to store large documents. Consequently, multiple storage cabins and places were created by companies just to store floppies. In 1998, around two billion floppy disks were sold around the world largely due to the fact that large numbers were required to store any sizeable data (BBC, 2007). Indeed, the original floppy disk could hold up to 100KB of data and then the memory was expanded to be able to hold around a three-minute song (BBC, 2007). By 2006, the global demand had tumbled by two-thirds to around 700 million as many PCs and laptop manufacturers started do away with the floppy drives (BBC, 2007). By early 2007, around 2% of PCs and laptops sold by the computing superstore PC World had built-in FDDs and even at this point the retailer also announced its decision to phase them out within a year (BBC, 2007). In the early years, the floppy disk was seen as “legendary” in offering computer users the ability to transfer data between locations (Thomas, 2010). Indeed, “floppies were as revolutionary as e-mail” (Watson, 2010, p. 17).

From the 1970s to the 2000s, the disk shrunk in size from its original 8 inches to 3.5 inches whilst capacity increased to around 1.5 megabytes. In 2010, Sony (a manufacturer of floppy disks) announced its decision to discontinue the production of the floppies on top of its earlier decision to terminate the manufacturing FDDs (Thomas, 2010). This was the final nail in the coffin in the development of the floppy disk. Table 1 illustrates the events in the evolution and demise of the floppy

disk. In the following section, other factors that contributed to the decline and near extinction are examined.

Insert Table 1 about here

5 Findings and analysis

The findings are presented in three distinguishable phases which articulate the rise to prominence, turbulence period precipitated by the introduction of new and improved data storage devices (1960s–1990s), decline (2000–2010) and phase-out (reconcile to aftermarkets) (2010 onwards). The floppy disk experienced its heydays from 1971 to the 1990s and then fortunes fluctuated which culminated in it being declared obsolete. In the late 1990s, the introduction of new storage devices provided the early warning signals of the eventual decline of the floppy disk.

5.1 Phase 1: The “new dawn”, 1971–1990s

In the early stage, multiple events and developments contributed to making the floppy disk a dominant format. One factor was its robustness and effective means of transferring data between computers. In 1973, the floppy was publicised as a “high speed” and “mass storage” devices following capacity improvements to 0.24 megabytes from the original 0.08 megabytes in 1971 (Thomas, 2010). More importantly, the capacity of the floppy was equivalent to around 3,000 punch cards and data could be accessed at a much faster pace than the tape (McKendrick & Wade, 2009). The period from 1978 to 1982 witnessed intense competition between the floppy disk and audio tape as a data storage medium for a large proportion of the home computer industry (Grant, 2010). It is interesting to note that in the 1980s, the floppy disk was seen as cutting-edge technology and a reliable medium for data

storage (Smith, 2013). Indeed, the floppy disk market was on the verge of a boom with a surge in global sales (Brunt, 1985).

By the 1980s, computers had moved from what was regarded as the “cossetted giants of the 1950s and 1960s” to become common equipment in many homes and offices in the developed world (Brunt, 1985, p. 35). Accompanying this was the increasing demand among users for higher-capacity storage devices. Many companies were able to store as much data as consumers with desktop computers were able to do by 2004 (The Economist, 2004). Consequently, it became standard practice across an array of industries for firms to discard data after the initial use when the extremely high cost of storage made it uneconomical to archive data after initial use (Perrons & Jensen, 2015). In the 1980s (referred to as the industry’s “stone age”), companies’ ability to store large amounts of data was severely limited by capacity constraints.

5.1.1 Capacity constraints and competing technologies, 1990s

Throughout the 1980s and then in 1990s, major factors helped to account for the decline of the floppy disk. The considerable limitations of the floppy disk became more evident. In the United States by the mid-1990s, the floppy disk had reached its highpoint in homes and offices (Smith, 2013). At the start of the 1990s, many computer programmes were distributed using the floppy disk, however, by the end of the decade a switch to the CD-ROM was witnessed, signalling the demise of the floppy disk (BBC, 2007). By the late 1990s, the limitations of the floppy disk became more apparent as more users demanded higher-capacity storage devices. In the 1990s, a DVD could store around 4.7 gigabytes of data on each side which was around seven times as much data as a standard CD, further exemplifying the demise and the mere 1.44MBspace of the floppy disk (Himowitz, 1999).

By the end of the 1990s, the appeal of the floppy disk had started fading fast. In the early 1990s, floppy disks had capacity for around 135 tracks per inch compared with the highest-density hard disks

which could hold 2,000 tracks per inch (Pollack, 1990). Even at the time, the optical compact disk was also capable of storing around 15,000 tracks per inch (Pollack, 1990). This exemplifies the limited capacity of the floppy disk relative to other storage devices in the early 1990s. As Watson (2010, p. 17) puts it:

“Like the tape drives they replaced, the technology began to feel clunky, unreliable and restrictive. As file and program sizes increased, floppy disks simply could not compete with newer inexpensive and larger-format storage formats such as Zip, CD, DVD, and eventually USB”.

Technological developments and technological breakthroughs in the storage industry played a pivotal role in sealing the fate of the floppy disk. The limited storage hampered the floppy’s ability to attract large segments of users. Perhaps the most significant event in signifying the need to shift to other storage devices was in 1998, when Apple launched the iMac without a floppy drive which was subsequently followed a few years later by Dell’s decision in 2003 to drop the floppy disk readers as standard equipment on desktops (Watson, 2010). Although the floppy superseded the tape drives and punch cards, by the late 1990s it appeared restrictive and unreliable relative to modern technologies at the time such as Zip, CD and DVD (Thomas, 2010).

Although the improvement of the CD technology led many to proclaim the death of the floppy in the 1990s, this failed to materialise by the end of this phase. Ultimately, the limited storage space and shrinking cost of data storage and other devices ultimately helped to seal the fate of the floppy disk. Given that companies also required so many floppy disks to store large data in the 1990s, boxes and warehouses/storage rooms were created just to store the disks. As technology continued to advance, hard-drive development accelerated and storage devices were also getting smaller and smaller with higher capacity (Long, 2005). Another factor was that firms with superior war chests and highly skilled employees began to emerge and they developed new and improved storage devices which eventually superseded the floppy disk.

5.2 Phase 2: The decline stage, 2000s

At the dawn of the 21st century, many global industries had come to be characterised by intense competitive rivalry, faster technological changes and shorter product lifecycles, thereby rendering many products and technologies obsolete (Eggers, 2014; Bartels et al., 2012). The argument that the world needed more high-capacity portable devices for the 21st century became a conventional wisdom among practitioners, inventors and system designers. The emergence of superior data storage devices with high capacity and reliability incentivised many consumers to switch away from the floppy disk. Above all, they were relatively cheaper compared with the rivals on the market in the 2000s (Johnson, 2002). At the outset of this period, the improvements in the development of portable drives made it increasingly easier to transport large data across long distances (Johnson, 2002).

By 2006, the cost has shrunk and fingernail-sized USB flash memory chips stored as much as 4 gigabits of data (Fortune, 2006). In response to growing opportunities, many data-storage companies have emerged offering different products for computer users (The Economist, 2000). The so-called “store wars” was the increasing number of venture capitalists offering support for many data storage start-ups and thereby helping to create conditions for the emergence of new firms offering high-capacity and robust storage devices (The Economist, 2000). In 2006, InPhase Technologies set a data storage record by attaining 515GB per square inch which was a higher capacity than conventional magnetic storage media (BBC, 2006).

By this stage, increasing obsolescence was more obvious as many PC manufacturers produced PCs without floppy drives and laptop manufacturers opted out of built-in floppy drives. To make matters worse, it became clear by the mid-2000s that the flash-based memory sticks and other high-capacity storage devices had “dethroned” the floppy disk as the easiest way to transfer and store data (The Economist, 2006). The cost of storage continued to decline and more firms emerged to offer free

online storage space. Furthermore, the information costs had shrunk to almost zero, as illustrated in Figure 3.

Insert Figure 3 about here

In the mid-1990s, the storage cost for one gigabyte of data on a hard drive was around £100, declining in the five years to around £50, and by 2006 the cost had fallen to around £1 (Morelle, 2006). Figure 4 demonstrates the evolution and emergence of different storage devices. When the CD-ROM was introduced, it had superior storage capacity and speed relative to the floppy disk. Since then, consumers and companies' needs to generate and store data have grown and more data are generated than ever before.

Insert Figure 4 about here

Portable drives and memory cards were smaller but capable of storing up to 16GB of data or more, gained prominence (BBC, 2015). Indeed, it would have taken up to 11,111 floppy disks to store 16GB of data (BBC, 2015). The availability of superior and new technologies such as CDs, digital versatile disks (DVD) and USB memory sticks encouraged many users to switch and eventually sealed the fate of the floppy disk. The evolution of storage devices can be classified and characterised as “technology vintage effect” (Bohlmann, Golder & Mitra, 2002), where a new generation of technologies outperforms the old technologies in terms of capacity, durability, reliability, ease-of-use, ease to transfer data and dependability. This created conditions which made it increasingly difficult for old data storage devices to compete.

The emergence of the DVD with higher capacity relative to the floppy disk began to take market share. The superior DVD performance and capacity offered consumers more options and brought

entertainment to many homes. The floppy disk was characterised by high cost and limited capacity. By 2007, there was an indication that technological advances and generation of new data had created a conducive environment for individuals and companies to hoard large quantities of data (The Economist, 2007). One of the main drivers was the continued decline in the cost of storing data. This was in sharp contrast to the previous decades where high cost of data storage discouraged storing any data. Another factor that accelerated the demise of the floppy during this period was the introduction of new and high-capacity storage devices.

One of the unique features of this period was that storage capacity was increasingly measured in gigabytes, terabytes or petabytes but rather than by the size of the warehouses required for the floppy disks and tapes, which characterised the preceding decades (The Economist, 2007). This meant that the extremely low-capacity floppy disks were no longer “fit for the job” as many companies and organisations switched to high-capacity storage devices. By 2007 or even much earlier, some of the USB memory sticks offered by retailers could store 2,000 times the capacity of the floppy disk, thereby further accelerating the switch away from the floppy disk (BBC, 2007). The emergence of new and improved USB memory sticks played a pivotal role in the reliance on the floppy as a key mechanism for data transfer.

The developments of cloud computing also provided many computer users with an additional opportunity to store their data in the cloud. Cloud-computing here refers to the situation where data are stored and analysed on remote servers, thereby reducing the need to acquire multiple storage devices to preserve data (The Economist, 2015). Cloud services such as Dropbox and Box provided alternative means to store data without having to own a physical storage device and mitigate data losses associated with physical possession of storage devices or misplacement of the storage device.

Amazon's Simple Storage Service or S3 was launched in 2006 and was one of the first major cloud-computing initiatives at the time (Hardy, 2012).

Online data storage companies such as Dropbox and Box have been offering some data storage space free which supersedes the size of the floppy disk. For instance, Google Drive provides 15GB of free storage and Box offers 50GB (Altman, Nagle & Tushman, 2015) relative to the standard 1.44MB capacity of the floppy disk. This was surprising given that in 1961 an IBM 1301 disk drive cost around \$115,500 (around \$900,000 in 2013 dollars) and was capable of storing a mere 28MB of information (Altman et al., 2015). These exemplified the significant drop in the cost of information storage over the decades. As more consumers began to use cloud-based data-storage services, the need to own low-capacity floppy disks or other storage devices was sharply reduced (The Economist, 2015; De Freytas-Tamura, 2013).

In recent years, the global cloud-computing market has seen significant growth as major firms such as Amazon Web Services, Microsoft and Google have expanded by building new data centres to take advantage of growth potential in the sector (The Economist, 2015). Unlike the floppy disk and subsequent inventions such as the CD and DVD, cloud computing has unlimited capacity to store data, thereby accelerating the demise of the floppy disk. In light of the growing need of individuals and businesses for high-capacity data-storage devices capable of storing multiple images, files and documents, many computer users eventually came to the conclusion that the floppy disk was incapable of meeting their expectations.

In the wake of the proliferation of numerous USB drives, Dell stopped incorporating 3.5-inch floppy drives in its computers in 2003 (Ulanoff, 2010). Although floppy disk sales peaked in the mid-1990s, by 2010 they had fallen 90% (Thomas, 2010). By this period, the continued decline in the cost of data storage meant that fewer data were being discarded for cost reasons (Komorowski, 2014). This was in

sharp contrast to the standard practice in the 1980s. By this point, some portable hard drives were capable of storing 1.5 terabytes of data, equivalent to thousands of floppy disks.

5.3 Phase 3: Phase-out stage

Phase-out stage refers to the period designated by the product manufacturer to discontinue production (Bartels et al., 2012). As many users transitioned from the floppy disk to the new data storage devices, manufacturers began to scale back their production before eventually ending large-scale production. During this period, a number of floppy manufacturers issued discontinuance notices to shops and users regarding their decision to stop production. In 2010, Sony announced the discontinuation of floppy disk manufacturing after nearly 30 years (Palmer, 2010). At the time of the announcement, it was clear that the world had moved on from the 1.44MB floppy disk which was incapable of holding a single average-length pop song or some single image from a digital camera (Grossman, 2010).

Another overriding issue was the decision by many computer manufacturers to stop incorporating the floppy drives in their machines (Palmer, 2010). One notable effect is that, over time, the demands of individuals and companies for capacity outstripped the capacity of the floppy disk to handle large data. More importantly, the emergence of single-storage devices capable of replacing millions of floppy disks sealed the fate of the floppy. The increasing capacity of portable hard drives also meant that firms could store data without having to incur high storage costs and build facilities to protect numerous floppy disks. Unlike other old-fashioned technologies such as vinyl (now revitalised to an extent after a period of decline) where enthusiasts have found new life in the aftermarket, the limited storage space, slow speed of data transfer and availability of superior storage devices has made it difficult for the floppy to find new life (Palmer, 2010).

6 Discussion and conclusions

The purpose of this study was to examine why and how some technologies become obsolete. Specifically, the paper examined the rise and fall of the floppy disk as a storage device from 1971 to 2010. The analysis led to the identification of three stages in the rise and fall of the floppy disk, i.e. the “new dawn”, 1971–1990s, the decline stage in the 2000s and then the phase-out period. From the 1970s to the 1990s, the floppy disk emerged as one of the leading storage devices propelled by its superior features and capacity relative to the old-fashioned punch cards and magnetic tape. However, new and superior storage devices emerged which superseded the features that made the floppy disk attractive up to the 1990s.

By the early 2000s the floppy was on a path of permanent decline precipitated by factors such as advances in the development of high-capacity portable devices, declining costs of storage and growth in the global cloud-computing market. The demise of the floppy disk can be traced not only to new technology development, but also to the convenience and reduction in storage costs offered by the superior alternatives. Over time, the superior features and appeal of the alternatives attracted more users, to the detriment of floppy manufacturers. Taken together, these factors interacted and influenced the process of obsolescence and the demise of the disk over the period. This paper develops a phase model to account for the underlying factors. Technology obsolescence can be viewed as an evolutionary phase model which entails the introduction of alternatives alongside the sale of the existing technology.

6.1 Contributions to theory

This study makes two further contributions to business history, strategy and technology literature. First, although recent years have witnessed a burgeoning stream of research on technology obsolescence (Sandborn & Singh, 2002), our understanding of the driving forces and processes leading

to a technology becoming obsolete remains largely overlooked (see Bartels et al., 2012). The foremost contribution this study makes lies in not only explicating the rise and fall of the floppy disk but also the underlying forces behind each stage. This study thus provides evidence to support the theoretical contention that technology obsolescence occurs over time and through multiple stages (Pecht & Das, 2000). Second, the preponderance of the evidence lends additional support to the theoretical contention that technology obsolescence stems from the emergence of alternatives with superior functionality and capacity (Shy, 1996; Altman et al., 2015). The accumulated evidence also attests to the contention that obsolescence also stems from the introduction of superior alternatives. By broadening and highlighting the historical aspects of the evolution and decline, this paper lends some support to the contention that history holds great in enriching our understanding of how industries change (Jones & Khanna, 2006).

6.2 Contributions to practice

From the dual perspectives of governments and practising managers, the study highlights the need for firms to continually upgrade expertise and formats in handling data. The advent of big data means that demand for high-capacity and reliable sources of storage are more likely to increase with cloud computing playing a pivotal role. Second, the study highlights the increasingly important role played by innovation in revealing the limitations of existing technology as well as altering the fate of such obsolete technology.

Regarding limitations, the findings articulated here must be approached with some caution. First, it would not be well grounded to generalise the findings beyond the context of the floppy disk. The approach adopted here is a single case event and might not be the only path leading to decline. Considerable further scholarly works are required to distinguish the different phases of decline and exit of different storage devices. Although the story of the floppy disk is not alone among storage devices that have become obsolete there is a need for future research to broaden our understanding of the other

formats. Further exploration of these formats would shed further light on why and how storage media such as punch cards and cassette tapes have come to be replaced whilst other obsolete technology such as vinyl finds new life in aftermarkets. Aftermarket refers to “the period after the original manufacturer has phased a part out of production” (Bartels et al., 2012, p. 168). It is hoped that this paper helps to bring into focus the faster pace from technology introduction to decline and some of the underlying dynamics.

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Table 1. Key events illustrating salient events in the demise of the floppy disk, 1971–2010

Phases	Chronology of Events
1970s	<ul style="list-style-type: none">• In 1971, the floppy disk was born when IBM commercialised technology designed to change tape drives.• In 1971, the 8-inch floppy disk entered the commercial arena with “massive” capacity of 80 kilobytes (0.08 megabytes) of data.• By 1972, the upgraded floppy could hold 0.12 megabytes of data.• In 1977, Apple presented the Apple II as a mass-produced computer with two 5¼-inch floppy drives.
1980s	<ul style="list-style-type: none">• In 1983, IBM launched the 10-megabyte hard disk to users.• In the 1980s, Sony pioneered the 3.5-inch floppy.• In 1988, CD sales surpassed vinyl.• In the mid-1980s, Fuji supported the 3.5 format with a range of disks from 250 kbyte to 1 Mbyte capacity and also launched a 5.25 in, 1.6 mbyte capacity disk.
1990s	<ul style="list-style-type: none">• In 1990, IBM launched personal computers with floppy disks 3.5 inches in diameter, capable of storing around 2.9 megabytes of information.• In 1991, CD sales surpassed cassettes, thereby announcing the rise of the CD as a prominent medium of data storage. It also confirmed the CD’s superiority to cassette, floppy disk and vinyl as sources of data/music storage.• In 1992, IBM introduced 3.5-inch disk drives to the market to offer up to 1.2 billion bytes of storage capacity. IBM shipped over 250,000 1-gigabyte 3.5-inch hard drives.• In September 1994, Fuji Photo Film Company announced that it had developed high-density floppy disk which made it possible to store more than 50 times the data than the old diskettes.• In 1995, IBM accomplished a new world record in magnetic data storage density – 3 billion bits of data per square inch.• In 1996 IBM achieved another technological breakthrough by setting a new record in magnetic data storage density – 5 billion bits of data per square inch.• In 1996, IBM also unveiled a pocket-sized 2.5-inch hard disk drive for mobile computers.

	<ul style="list-style-type: none"> • In 1996, there were around five billion floppy disks in circulation. • in 1998, when the iMac was shown without a floppy disk drive many pronounced the death of the floppy disk which was premature. • In 1998, Apple launched the iMac G3 with USB but without the floppy disk drive, thereby firing the first warning shot of the demise of the floppy disk.
2000s	<ul style="list-style-type: none"> • In 2003, Dell removed disk drives from higher-spec machines, thereby rendering the storage device closer to extinction. • In 2005, the iPod nano was launched which relied on small memory chips capable of retaining data even when power was switched off. It was projected that the flash-memory chips would eventually displace other storage technologies. • In 2005, the global sales of flash chips surpassed \$19 billion. • In 2006, InPhase Technologies set a data storage record by attaining 515 gigabits per square inch which was a higher capacity than conventional magnetic storage media. • In 2009, Hitachi Maxell and Mitsubishi Kagaku Media decided to end floppy disk manufacturing. • In 2010, Sony announced discontinuation of the manufacturing the floppy disks after nearly 30 years. • In 2010, the floppy was declared an “obsolete format”. • Cloud computing projected as the way forward into data storage and would eventually displace other storage media. • “The age of cloud computing” was declared. • The “era of big data” began with intensity. For instance, the Large Hadron Collider in 2010 alone generated 13 petabytes of data (13m gigabytes) exemplifying the need for high-capacity storage devices to assist research and development efforts.

Data sources: synthesised from: Brunt, 1985; IBM, 2014a, 2014b, 2015; Watson, 2010; BBC, 2006, 2007; Palmer, 2010; Fiegerman, 2010; Ulanoff, 2010; Pollack, 1990, 1994; Thomas, 2010; The Economist, 2006; Naughton, 2012; Lynskey, 2015; Afuah & Tucci, 2003.

Figure 1: Technology obsolescence and revolutions as a process model

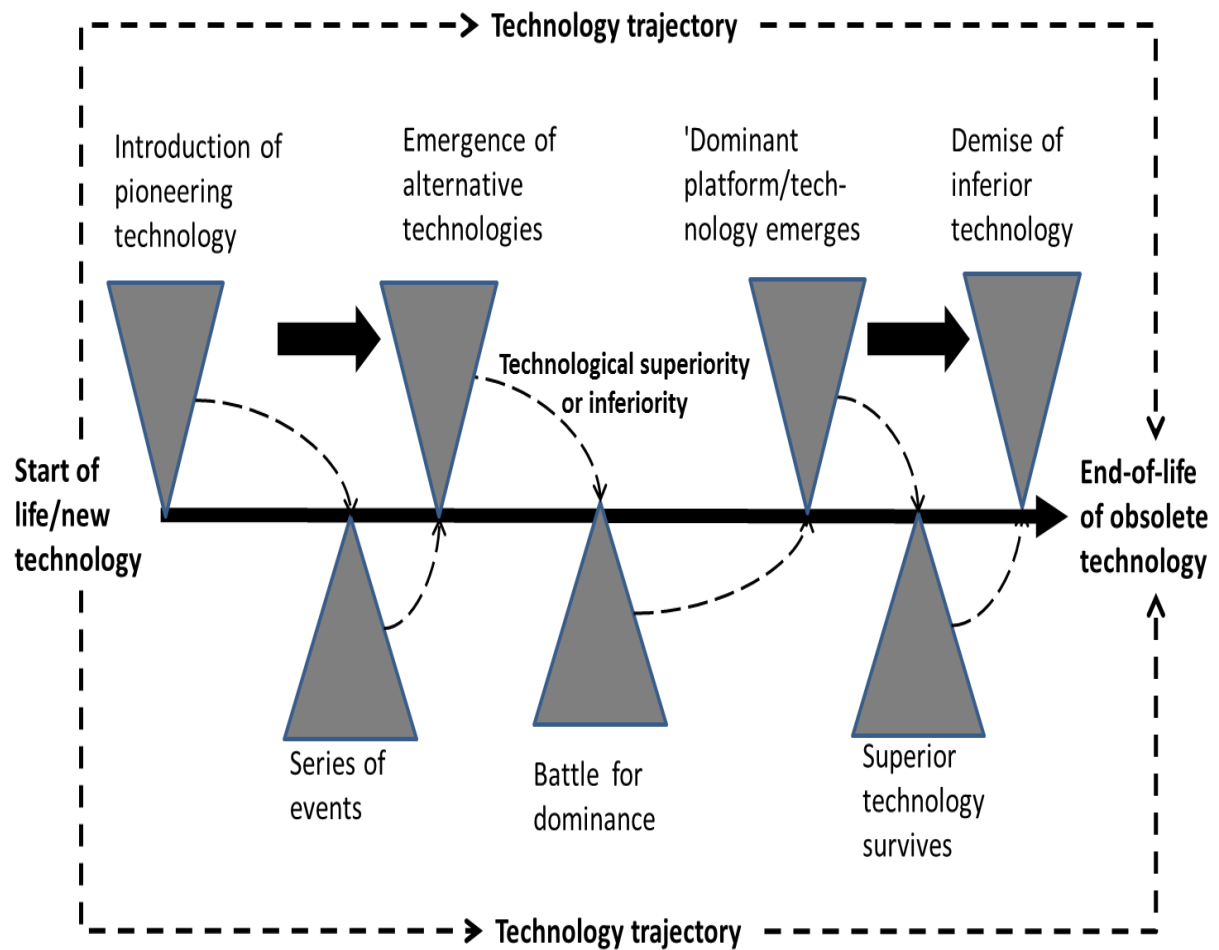


Figure 2: Stages in the evolution of the demise of the floppy disk

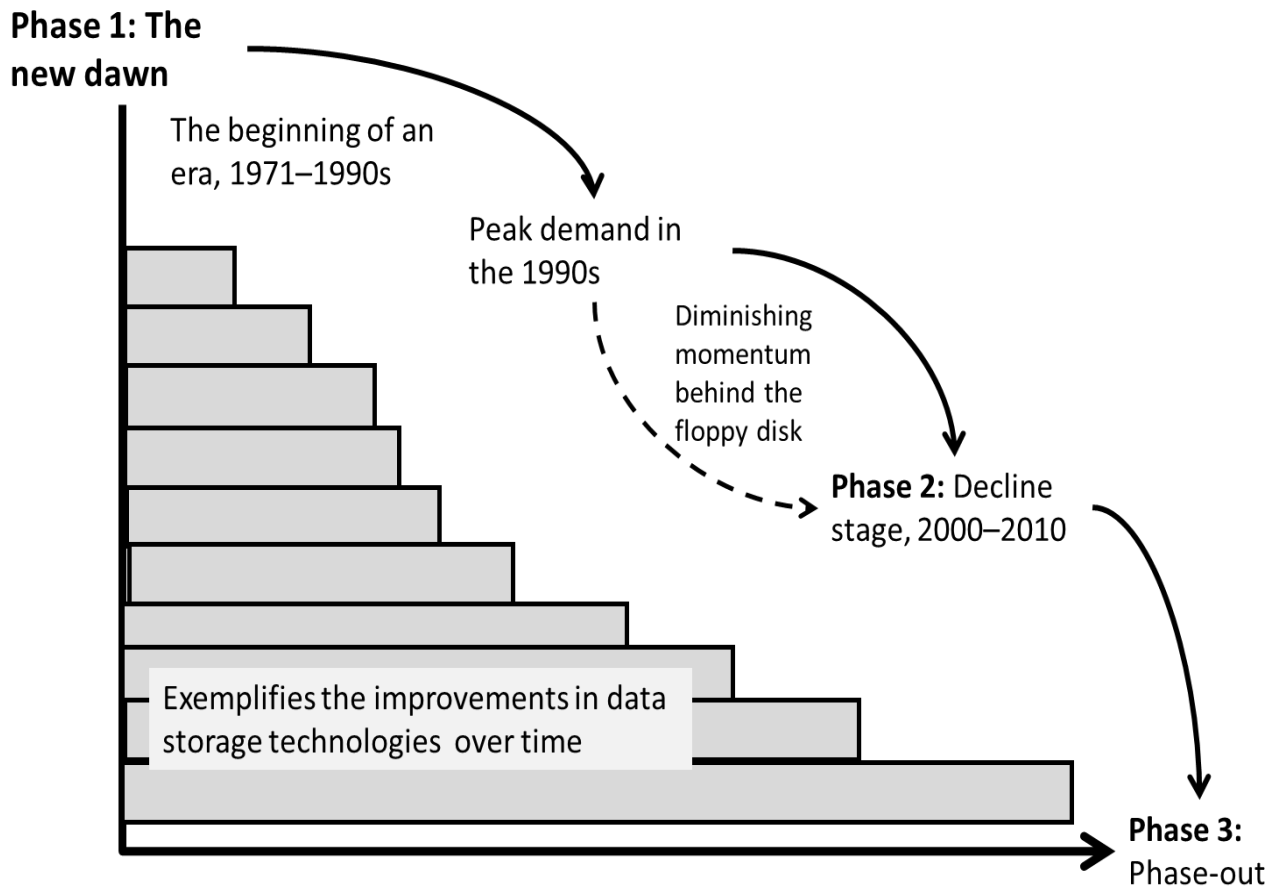
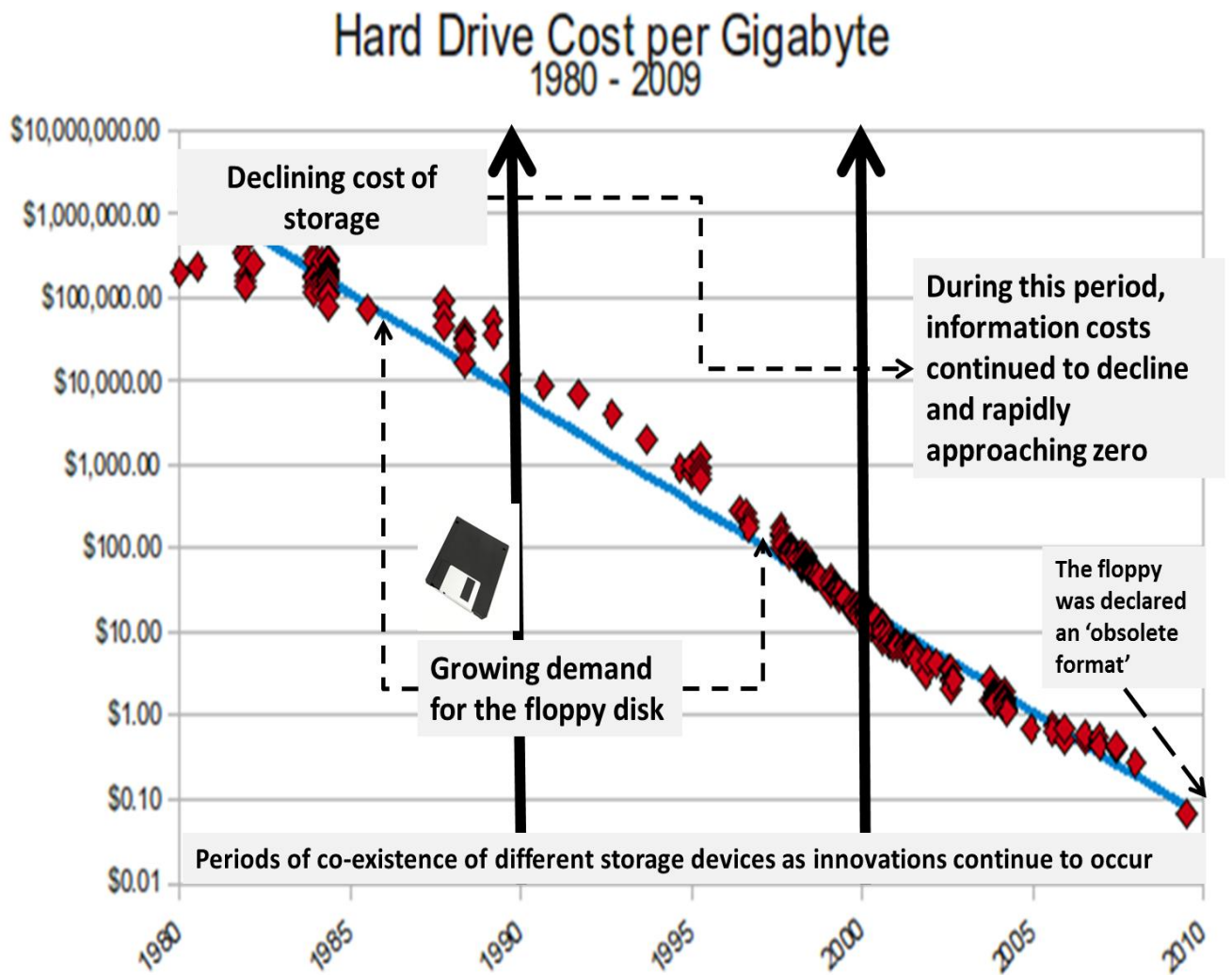


Figure 3: Declining cost of storage



Data source for the trend on storage cost: Komorowski, 2014.

Figure 4: Evolution of data-storage devices

